CHAPTER 840
SUBSURFACE DRAINAGE

Topic 841 - General

Index 841.1 - Introduction

Saturation of the structural section or underlying foundation materials is a major cause of premature pavement failures. In addition, saturation can lead to undesireable infiltration into storm drain systems and, where certain soil types are below groundwater, liquefaction can occur due to seismic forces. Subsurface drainage systems designed to rapidly remove and prevent water from reaching or affecting the roadbed are discussed in this chapter.

The solution for subsurface drainage problems often calls for a knowledge of geology and the application of soil mechanics. The Project Engineer should request assistance from the Roadway Geotechnical Unit in the Engineering Service Center for projects involving cuts, sections depressed below the original ground surface, or whenever the presence of groundwater is likely. The Roadway Geotechnical Unit can also provide assistance related to the design of features to relieve hydrostatic pressure at bridge abutments. The designer should consider the potential for large fluctuations in groundwater levels. Wet periods after several years of drought, or changes to recharge practices can lead to considerable rises in groundwater levels.

For tunnel, structure abutments, or other structure projects which might require relief of hydrostatic pressures, contact the Structure Foundations Branch of the Engineering Service Center.

The basis for design will generally be the Geotechnical Design Report. This report will include findings on subsurface conditions and recommendations for design. Refer to Topic 113 for more information on Geotechnical Design Reports.

There are many variables and uncertainties as to the actual subsurface conditions. In general, the more obvious subsurface drainage problems can be anticipated in design; the less obvious are frequently uncovered during construction. Extensive exploration and literature review may be required to obtain the design variables with reasonable accuracy.

841.2 Subsurface (Groundwater) Discharge

Groundwater, as distinguished from capillary water, is free water occurring in a zone of saturation below the ground surface. Subsurface discharge, the rate at which groundwater and infiltration water can be removed depends on the effective hydraulic head and on the permeability, depth, slope, thickness and extent of the water-bearing formation (the aquifer). The discharge can be obtained by analytical methods. Such methods, however, are usually cumbersome and unsatisfactory; field explorations will yield better results.

841.3 Preliminary Investigations

Field investigations may include:

- Soils, geological, and geophysical studies.
- Borings, pits, or trenches to find the elevation, depth, and extent of the aquifer.
- Inspection of cut slopes in the immediate vicinity.
- Measurement of groundwater discharge.

Preliminary investigations should be as thorough as possible, recognizing that further information is sometimes uncovered during construction. Where an existing road is part of new construction, the presence and origin of groundwater is often known or easily detected. Personnel responsible for maintenance of the existing road are an excellent source of such information and should be consulted. Explorations, therefore, are likely to be lesser in scope and cost than explorations for a project on new alignment. In slope stability questions, and other problems of equal importance, an extensive knowledge of subsurface conditions is required. The District should ask for the assistance of the Office of Structural Foundations in the Engineering Service Center in such cases.

841.4 Exploration Notes

In general, explorations should be made during the rainy season or after the melting of snow in regions where snow cover is common. An exception would be where seepage occurs from irrigation sources.

Groundwater difficulties frequently stem from water perched on an impermeable layer some distance above the actual water table. Perched water problems can often be solved with horizontal drains. See Index 841.5.

Pumped water supply wells often give unreliable indications of the water table and such data should be used with caution.

841.5 Category of System

Depending upon the scope and complexity of the problem, an appropriate solution may require the installation of one or a combination of different types of subsurface drainage systems. The type of subsurface drainage system initially considered is usually an underdrain.

The standard underdrain is the pipe underdrain. A pipe underdrain consists of a perforated pipe near the bottom of a narrow trench lined with filter fabric and backfilled with permeable material.

Pipe underdrains are discussed in more detail under Topic 842.

"French Drains" have proven to be unreliable underdrains. A "French drain" consists of a trench backfilled with rock. They are not to be used where a permanent solution is needed. Exceptions may be made for special cases such as where depth of the underdrain and soil conditions would conflict with industrial safety regulations. Under such circumstances a design that includes a filter fabric liner and permeable material backfill, without the perforated pipe may be used.

In addition to pipe underdrains, the following special purpose categories of subsurface drains are used to intercept, collect, and discharge groundwater.

- *Structural Section and Edge Drains.* Subsurface drainage systems that are primarily designed for the rapid removal of surface water infiltration from treated or untreated pavement structural section materials are called structural section drains or more typically edge drains. An 80 mm slotted plastic pipe with 3 rows of slots is the standard for structural section drains. Structural section drainage is discussed under Topic 606.

- *Horizontal Drains.* Horizontal drains are 40 mm perforated or slotted pipes placed in drilled holes bored into the aquifer or water bearing formations. They are installed in cut slopes and under fills more to guard against slides by relieving hydrostatic pressure than to prevent saturation of the roadbed. They may be used in varying lengths up to 300 m on grades that range from 0 to 25 percent. A collection system to remove the intercepted water from the area is generally also required.

  An example of a horizontal drain system is illustrated in Chapter C5 of the Maintenance Manual.

- *Prefabricated Geocomposite Drains.* Available in sheets or rolls, geocomposite drains provide a cost effective solution to subsurface drainage behind bridge abutments, wingwalls and retaining walls. Prefabricated subsurface drainage systems consist of a plastic drain core covered on one or both sides with a filter fabric.

- *Stabilization Trenches.* This category of subsurface drainage system is constructed in swales, ravines, and under sidehill fills to stabilize water logged fill foundations. The Geotechnical Design Report should contain depth and width of trench recommendations. Stabilization trenches may be only a few feet in width requiring a backhoe or similar type of excavation equipment, or they may be large enough for earth moving equipment such as dozers and scrapers to operate. Trenches wide enough to permit the use of earth moving equipment should be considered wherever feasible. A 1:1 side slope is commonly used.

The excavated trench, including the side slopes, is covered with a thick blanket of permeable material. One or more perforated drain pipes, usually 200 to 300 mm in diameter, are placed at the bottom of the trench depending on the quantity of groundwater, type of material, and area to be stabilized.

The alignment of the trench and collector pipe are often made parallel to the highway centerline. Conditions may be such that trench alignment on a skew or with tee, wye, or herringbone configurations are a better design.

Lining the trench with filter fabric is recommended. The usual one meter or more thickness of permeable material may be reduced and a less expensive gradation may be specified if a filter fabric is used. Assistance in selecting filter fabric and permeable material specifications should be requested from the Geotechnical Branch or Geotextile Unit of the Engineering Service Center.

- *Drainage Galleries*. Drainage galleries consist of a row or rows of closely spaced wells 900 to 1200 mm in diameter bored with power augers to the depth required to intercept the aquifer. They are a variation of the stabilization trench principle and may afford a more cost effective solution under certain conditions.

  Drainage galleries are a viable option where the depth of the aquifer exceeds the economical or practical limits for open trench excavation. Because of potential cave-ins or slides, open trench excavation may not be practical.

  The bottom of the bored wells should be interconnected and a suitable collector and outlet system must be provided. The wells may be interconnected by belling out at the bottoms, tunneling between wells, drilled-in-place outlets, or horizontal drains.

  The wells are backfilled with permeable material. The Geotechnical Design Report should contain well spacing and depth recommendations. Assistance in selecting permeable material and other specifications pertinent to drainage galleries should be requested from the Office of Structural Foundations in the Engineering Service Center.

Topic 842 - Pipe Underdrains

842.1 General

As stated under Index 841.5, the standard underdrain treatment is the perforated pipe underdrain. Pipe underdrain systems consist of a 150 or 200 mm diameter perforated pipe placed near the bottom of a narrow trench. The trench is usually lined with filter fabric prior to placement of the perforated pipe and permeable material backfill.

Two standard cross sections for pipe underdrains are shown on Standard Plan D102. The one with the permeable material carried to the top of the grading plane is used under paved areas. The other, with a topping of earth backfill over the permeable material, is used under unpaved areas.

842.2 Single Installations

A single pipe underdrain is commonly used in these cases:

- Along the toe of a cut slope to intercept seepage when slope stability is not a problem.
- Along the toe of a fill on the side from which groundwater originates.
- Across the roadway at the downhill end of a cut.

842.3 Multiple Installations

Multiple underdrain installations may be used in a herringbone or other effective pattern in situations such as the following:

- Under the roadway structural section when a permeable blanket is required.
- To stabilize fill foundation areas.

Refer to Table 842.4 for a guide to selecting depth and spacing of multiple pipe underdrain installations.

842.4 Design Criteria

- *Size and Length*. For pipe underdrains of 150 m or less in length, the standard perforated pipe size is 150 mm in diameter. As a rule, the 150 mm diameter is adequate for collectors and laterals in most soils. For lengths exceeding 150 m, the minimum diameter of pipe is 200 mm.
- *Surface Runoff*. Surface drainage should be prevented from discharging into underdrain systems.
- *Outlets*. Underdrain outlets should be provided at intervals of not more than 300 m.

  Underdrain systems may be designed to discharge directly into a storm drain or culvert as long as the underdrain outlet is not subjected to hydrostatic pressures that could cause backflow damage.
- *Cleanouts*. Terminal and intermediate risers may be placed for the convenience of the maintenance forces cleaning the system. When practical, a terminal riser should be placed at the upper end of an underdrain. Intermediate cleanout risers may be placed at intervals of 150 m and at sharp angle points greater than 10 degrees.

  The diameter of risers should be the same as the pipe underdrain. Details of underdrain risers are shown on Standard Plan D87-B.
- *Grade*. If possible, pipe underdrains should be placed on grades steeper than 0.5 percent. Minimum grades of 0.2 percent for laterals and 0.25 percent for mains are acceptable.
- *Depth and Spacing*. The depth of the underdrain depends on the permeability of the soil, the elevation of the water table, and the amount of drawdown needed to ensure stability. Whenever practicable, an underdrain pipe should be set in the impervious zone below the aquifer. Additionally, consideration should be given to the depth and proximity of storm drains. Typically, the underdrain should be placed at a depth sufficient to keep the storm drain above the groundwater table.

  Table 842.4 gives suggested depths and spacing of underdrains according to soil types. It is only a guide and should not be considered a substitute for field observations or local experience.

842.5 Types of Underdrain Pipe

The aim of any underdrain installation is long term effectiveness. This aim is associated with filtering ability, durability, strength, and cost of conduit, mainly in that order. In choosing between pipes of different types, the key considerations are filtering ability and durability. Pipe cost assumes secondary importance because it is a minor part of the underdrain investment.

Pipes for underdrains are perforated and may be made of steel, aluminum, polyvinyl chloride (PVC) or polyethylene, all with corrugated profiles, or smooth wall PVC. All of the listed types are acceptable for either shallow or deep burial situations. Where plastic pipe underdrains are proposed and burial depths would exceed 10 m, the Underground Structures Unit in the Engineering Service Center should be contacted for approval.

842.6 Design Service Life

Refer to Chapter 850 for further discussion and criteria relative to design service life of pipe materials used in underdrain installations.

Experience with underdrains has shown that they are not subject to corrosion in an environment that lacks an adequate supply of air and oxygen entrained in the water. Subsurface waters that may be inclined to be corrosive chemically do not tend to become so as long as they are not exposed to oxygen. However, subsurface water may become corrosive after it has surfaced and been exposed to oxygen. Furthermore, there is evidence that indicates there is little oxygen available in long lengths of the small diameter pipe normally used in a subsurface drainage system.

Although tests may indicate that corrosive salts are present in the soil solution, corrosion will not take place without the presence of oxygen. Therefore, when it is anticipated that the underdrain will be placed to intercept groundwater under the above conditions, it will not be necessary to allow for metal pipe corrosion.

When the above conditions do not prevail, the design service life of metal pipe is determined from pH and resistivity tests covered in California Test 643. This information is shown in the Materials Report. The design service life of steel pipe may be increased by a bituminous coating as indicated in Table 854.3A.

The guide values contained in the tables mentioned above may be modified where field observation of existing installations dictates.

842.7 Pipe Selection

In cases where more than one material meets the foregoing requirements, alternatives should be specified on the basis of optional selection by the contractor. The selection of a single type of underdrain may be appropriate due to other related factors. This selection should be supported by complete analysis of factors and documentation placed on file in the District.

Table 842.4

Suggested Depth and Spacing of Pipe Underdrains for Various Soil Types

Soil Class	Soil Composition			Drain Spacing (m)			
	Percent Sand	Percent Silt	Percent Clay	1.00 m Deep	1.25 m Deep	1.50 m Deep	1.75 m Deep
Clean Sand	80-100	0-20	0-20	35 - 45	45 - 60	- -	- -
Sandy Loam	50-80	0-50	0-20	15 - 30	30 - 45	- -	- -
Loam	30-50	30-50	0-20	9 - 18	12 - 24	15 - 30	18 - 36
Clay Loam	20-50	20-50	20-30	6 - 12	8 - 15	9 - 18	12 - 24
Sandy Clay	50-70	0-20	30-50	4 - 9	6 - 12	8 - 15	9 - 18
Silty Clay*	0-20	50-70	30-50	3 - 8	4 - 9	6 - 12	8 - 15
Clay*	0-50	0-50	30-100	4(max)	6(max)	8(max)	12(max)

* Drainage blankets or stabilization trenches should be considered.